SMART SENSORS

What we will study here?

- ✓ Basics of sensors
- ✓ Overview of Smart Sensor
- ✓ Description of the architecture of a smart sensor
- ✓ Operation
- ✓ Evolution of smart sensors
- ✓ Applications

Introduction:-

A sensor is basically an element that produces a signal relating to the quantity to be measured. For example let us consider an electrical resistance temperature element. Here the measurand is the temperature which is being sensed by the said device and it produces an electrical resistance from the temperature being measured.

General Characteristics:-

Static Characteristics:

- Accuracy
- Precision
- Reproducibility & Repeatability
- Range and span
- Sensitivity
- Signal to noise(S/N) ratio
- Linearity
- Hysteresis

General Characteristics:-

Dynamic Characteristics:

- Frequency and Impulse responses
- Speed of the response
- Measuring lag
- Fidelity
- Dynamic error

Classification of sensors:-

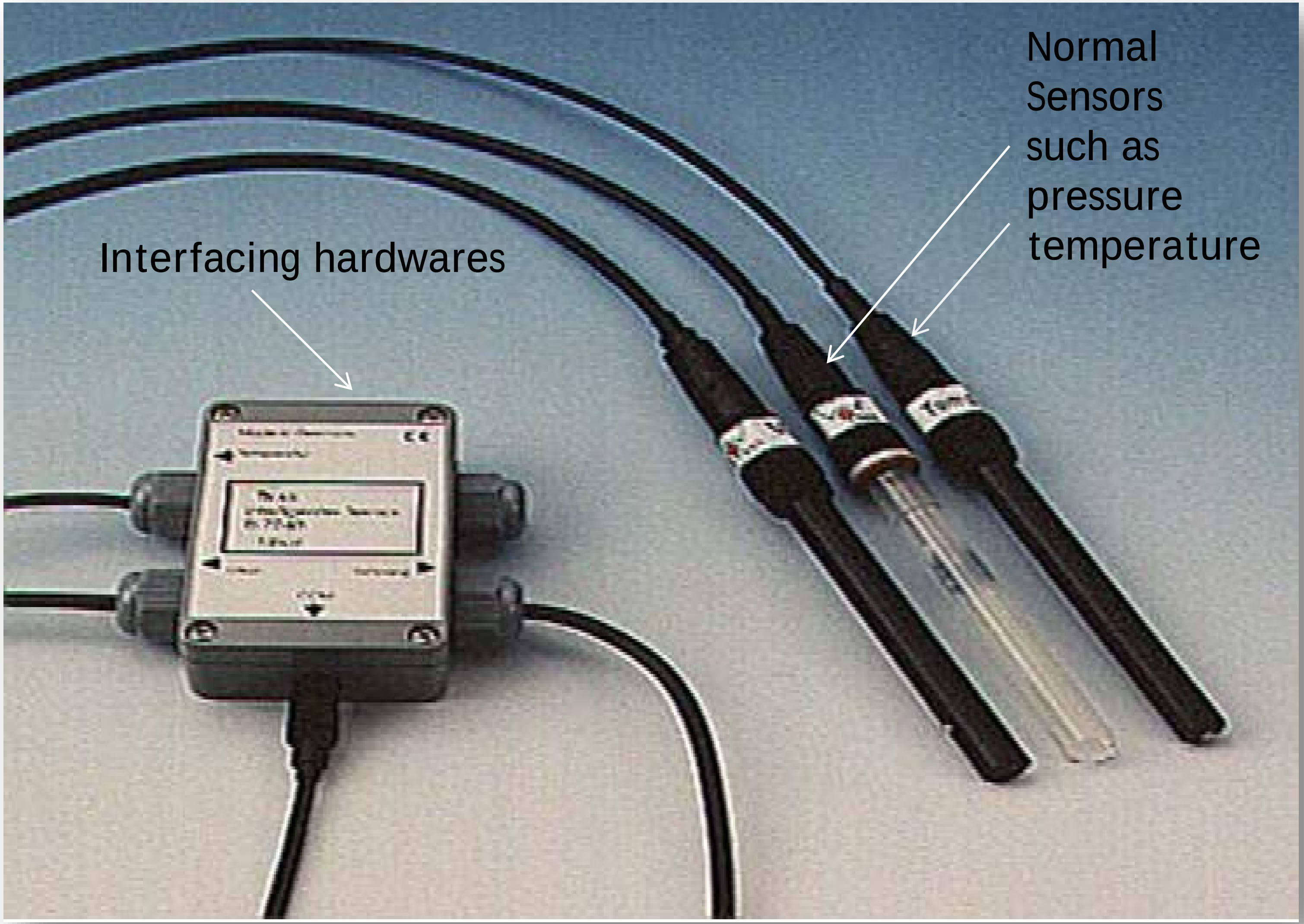
Sensor Types	Examples
Flow	Differential Pressure, Electromagnetic, Ultrasonic
Level	Mechanical, DP, Magnetostrictive, radio frequency
Temperature	RTD, Thermistor, Thermocouple,
Displacement	Potentiometric, LVDT, Capacitive, Photoelectric
Acceleration	Accelerometer, Gyroscope
Image	CMOS,CCDs
Chemical	Ionization, Infrared, Semiconductor
Biosensor	Electrochemical, SPR,LAP
Others	Mass, Force, Humidity, Viscosity

What is a Smart Sensor?

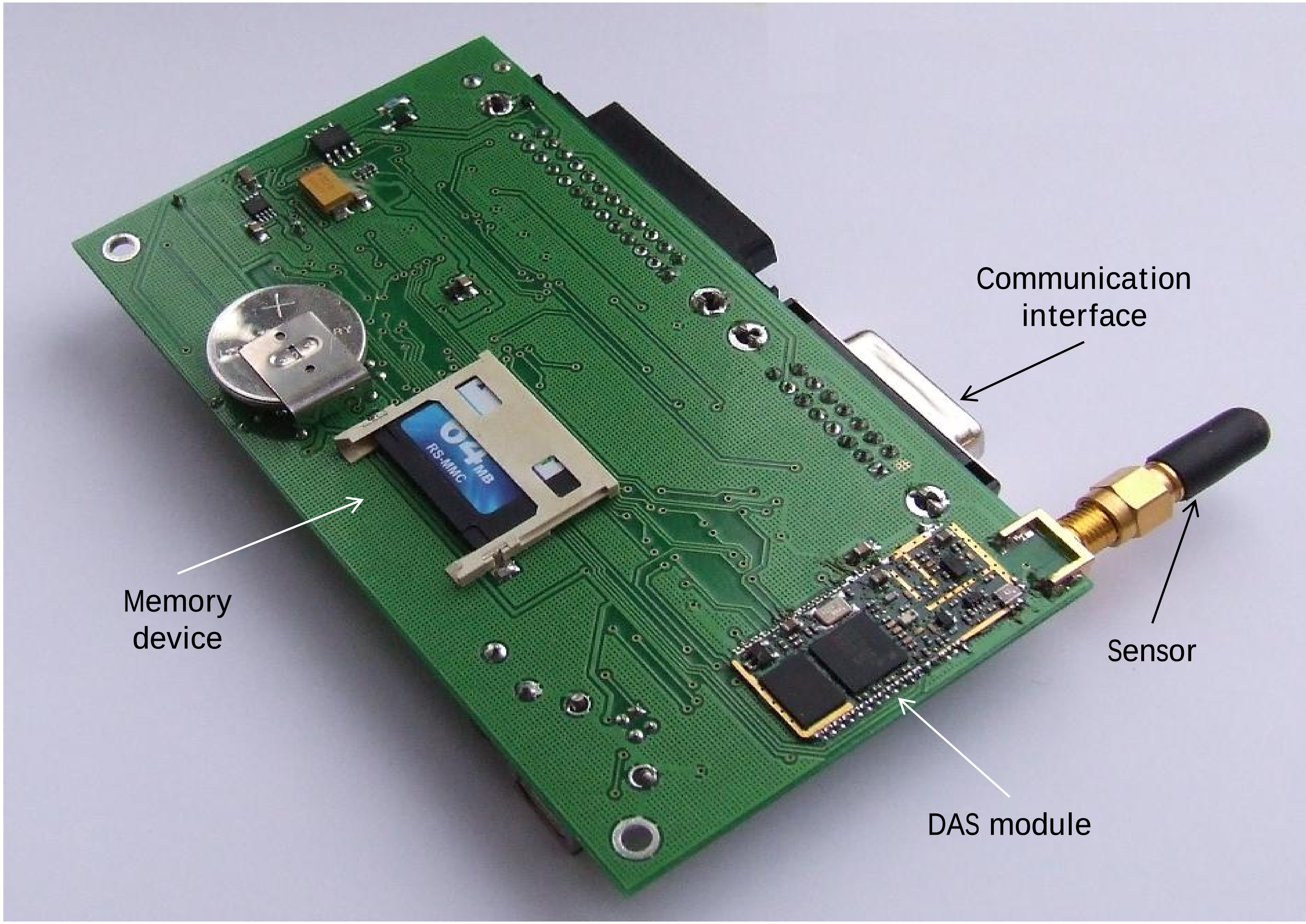
A sensor producing an electrical output, when combined with some interfacing hardwares is termed to be an **intelligent sensor.** Intelligent sensors are also called **smart sensors**, which is a more acceptable term now.

Sensors + Interfacing hardwares=Smart sensors

This type of sensor is different from other type of sensors as because it carries out functions like ranging, calibration and decision making for communications and utilization of data.

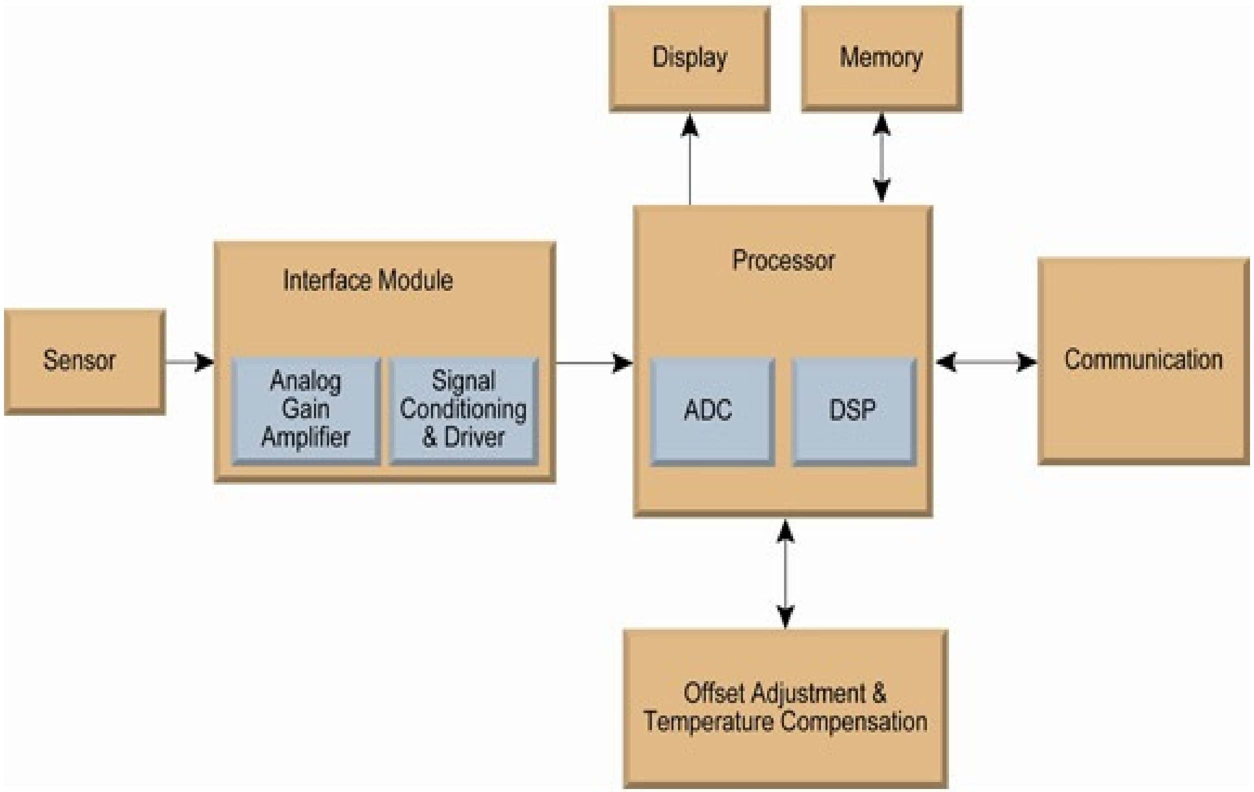


Smart Sensor



Smart Sensor

Block Diagram:-

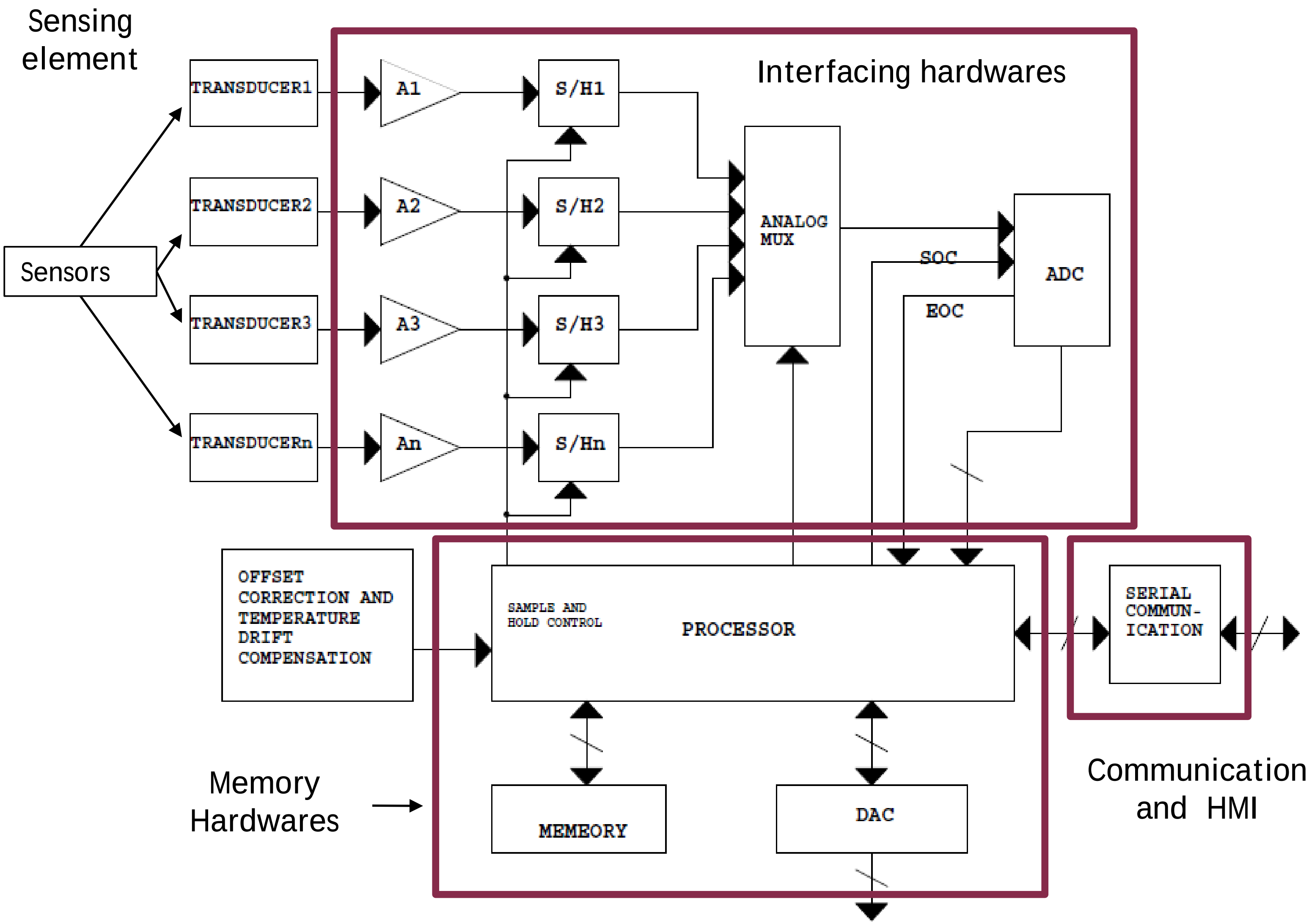


Smart Sensor

Features:-

- Automatic ranging and calibration of data through a built in system.
- Automatic DAS and storage of calibration constants in local memory of the field device.
- Automatic linearization of nonlinear transfer functions.
- Auto-correction of offsets, time and temperature drifts.
- Self tuning control algorithms.
- Control is implementable through signal bus and a host system.
- Initiates communication through serial bus.

Architecture of a smart sensor:-



GENERAL ARCHITECTURE OF SMART SENSOR

The general architecture of a smart sensor has the following components namely

- Sensing element and transduction element.
- Interfacing Hardwares/Data Acquisition System (DAS)

  Signal Conditioning Devices.

  Conversion Devices.
- Programming Devices.
- Communication Interfaces.

Description of the components

Sensing element and Transduction element:

It is the first component of the sensor system that comes in contact with the *measurand*. The measurand can be any form like pressure,flow,level, temperature etc.

This element is also termed as the primary sensing element of a measurement system.

Data Acquisition System (DAS):

A DAS is used for the measurement and processing of an input response or any measurand before it is being displayed on the operator desk or permanently recorded and monitored. Following are the components to accomplish the necessary tasks.

- Transducers.
- Signal Conditioning and Signal Processing Unit.
- Conversion elements like ADC/DAC.
- Multiplexer and Demultiplexer.

Transducers:

A transducer in general is a device that converts one form of energy to another form. Transducers change the physical phenomena into electrical signals.

A common example is RTD that converts the temperature into corresponding electrical signal that is measured in terms of voltage or resistance.

Resistance Temperature Detector

Signal Conditioning and Signal Processing Unit:

The process of manipulating and modifying the input signal or measurand in such a way that it meets the necessary requirements for further processing. Signal conditioning of an input signal is done through the following steps

- Amplification
- Filtering
- Linearization
- Sampling
- Modulation
- Excitation

Amplification: Process of boosting up the input signal for the purpose of increasing the resolution and reducing the noise.

Filtering: Extended process of amplification stage to remove the unwanted noise components present in the signal of interest. The noise components can be removed using LPF and HPF depending on the input signal.

Linearization: Process of converting a non linear response into a linear one for better output response.

Sampling: Process of conversion of a continuous signal into a discrete signal.

Modulation: Transmitting the input signal carrying useful information to a remote site appended with a carrier signal depending on the channel bandwidth and frequency.

Excitation: Signal conditioning also generates excitation for some passive transducers such as strain gauge, RTD which acquire external voltages for their operation.RTD measurements are usually made with a current excitation source that converts the change in resistance into a measurable voltage.

ADC and DAC converters:

The data converters convert one form of data into another form. There are two types of data converters

Analog to Digital Converter(ADC)
Digital to Analog Converter(DAC)

Analog to Digital Converter (ADC):

An analog-to-digital converter is a device that converts a continuous physical quantity (usually voltage) to a digital number that represents the quantity's amplitude.

The conversion is done through 3 steps

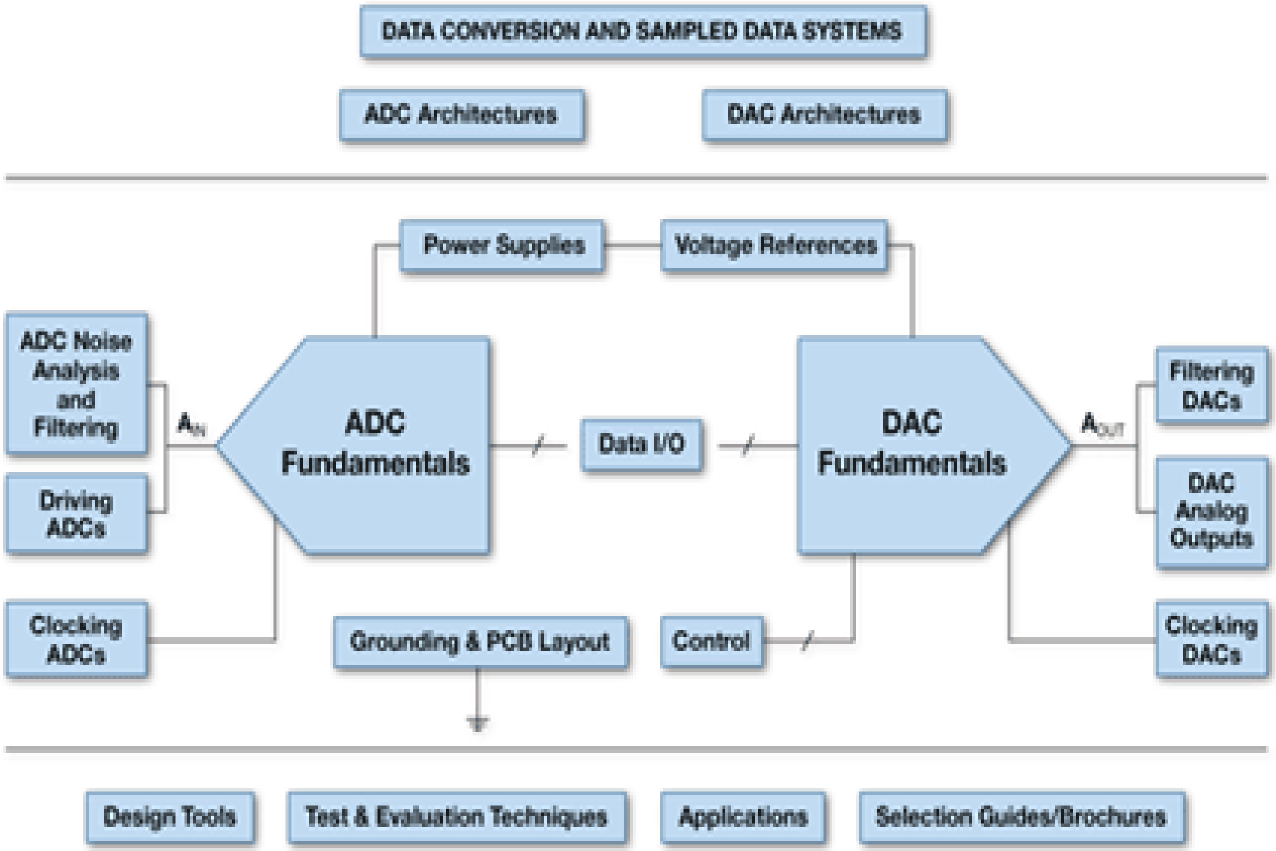
Sampling

Quantization

Coding

Digital to Analog Converter (DAC):

A device that converts a digitised input signal into its continuous analog output signal(current, voltage or electric charge).



Data conversion and sample data system

Sample and Hold Circuit (S/H):

Sample and hold circuit is an analog device that samples the voltage of a continuously varying analog signal and holds its value at a constant level for a specified minimal period of time.

They are typically used in analog-to-digital converters to eliminate variations in input signal that can corrupt the conversion process.

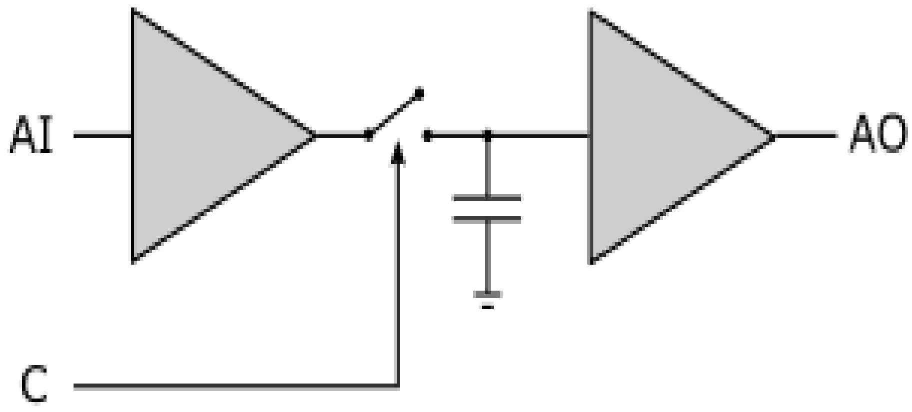


Fig: Sample and Hold circuit: AI=Analog Input, AO=Analog Output
C=control signal

The sample and hold circuit stores electric charge in a capacitor and contains a switch and at least one operational amplifier. To sample the input signal the switch connects the capacitor to the output of a buffer amplifier. The buffer amplifier charges or discharges the capacitor so that the voltage across the capacitor is practically equal, or proportional to, input voltage. In hold mode the switch disconnects the capacitor from the buffer. The capacitor is invariably discharged by its own leakage currents and useful load currents.

Multiplexer and Demultiplexer:

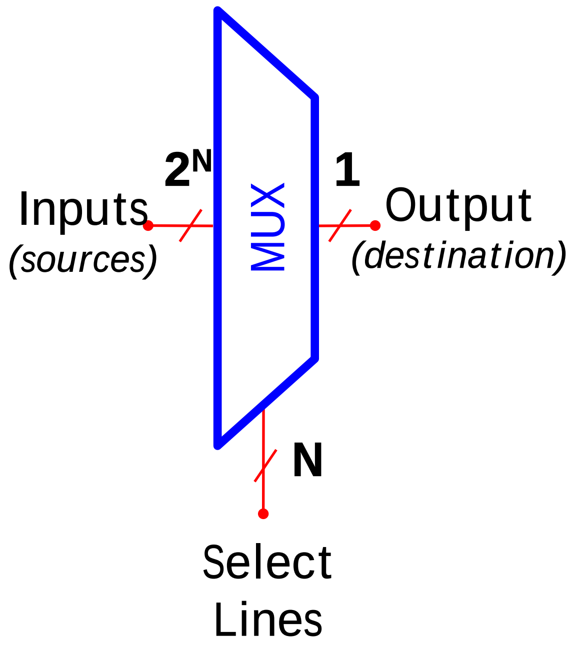
Multiplexer(MUX):

is a device that selects one of several analog or digital input signals and forwards the selected input into a single line. A multiplexer of 2^n inputs has n select lines, which are used to select which input line to send to the output.

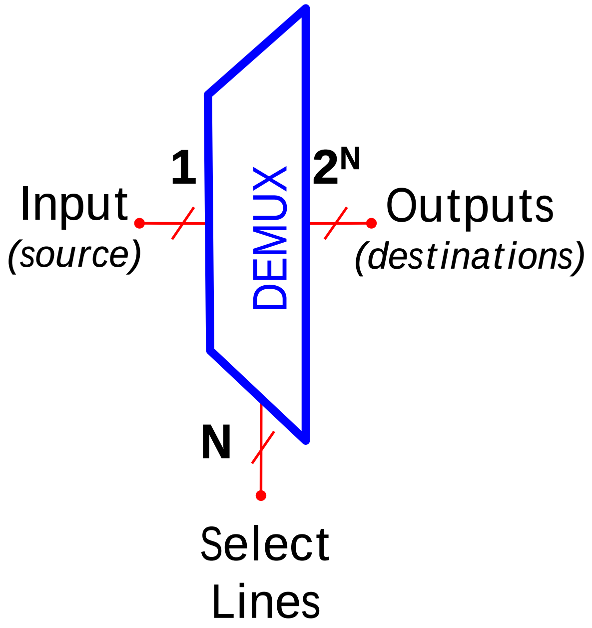
Demultiplexer(DEMUX):

is a device that produces multiple number of outputs from a single input. A demultiplexer with a single input and 2^n outputs has n select lines.

Block diagram of MUX



Block diagram of DEMUX

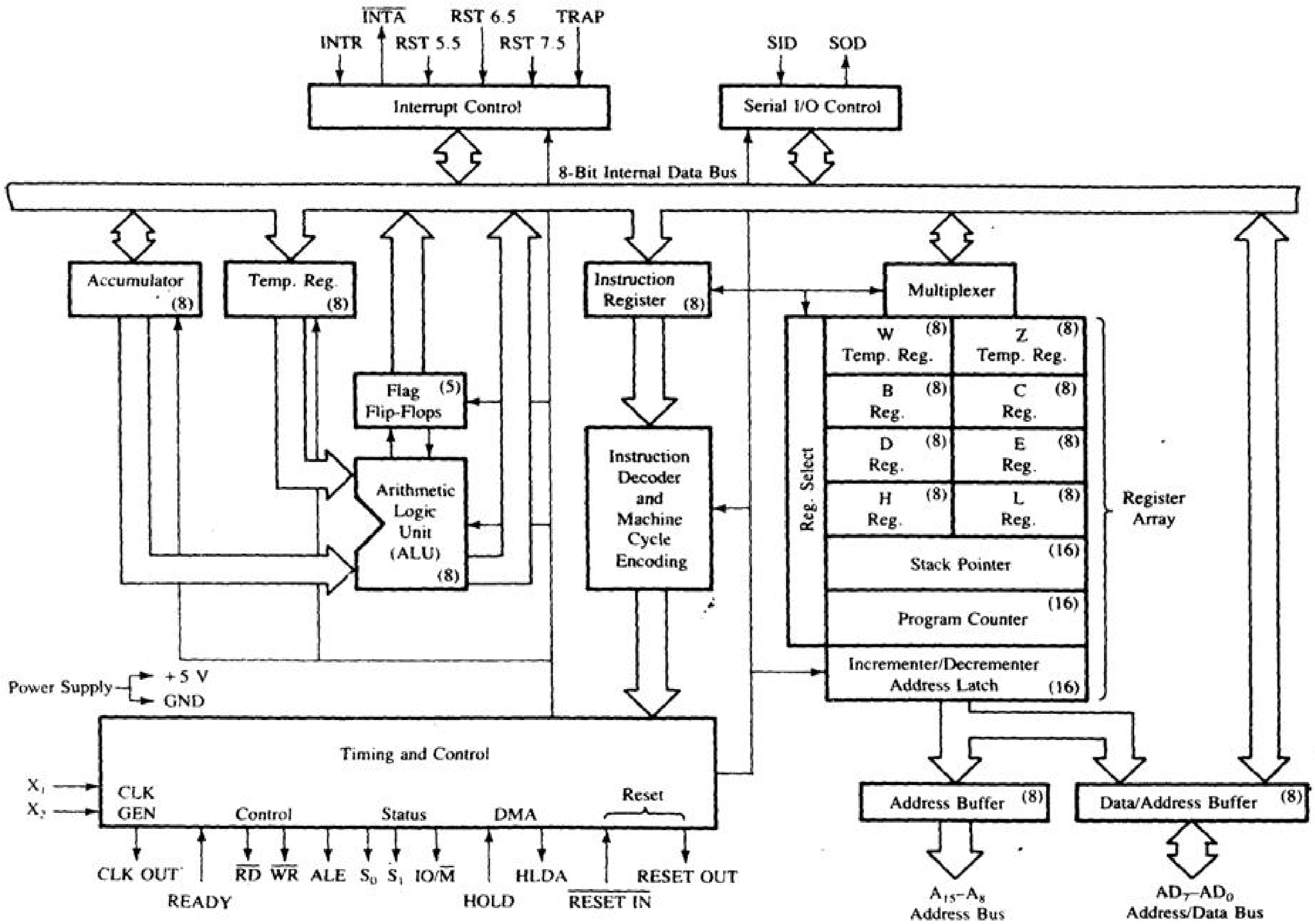


Programming Devices:

After the data acquisition process is over, the processed signal is fed into the programming devices such as *microprocessor* for the purpose of programming and storage of the programmed data in the memory devices.

Microprocessor (8085)-a brief introduction:

A microprocessor is a multipurpose, programmable, clock driven register based electronic device that reads binary instructions from a storage device called memory, accepts binary data as input and processes data according to those instructions and provides results as output.



Architecture of 8085 microprocessor

Communication interfaces:

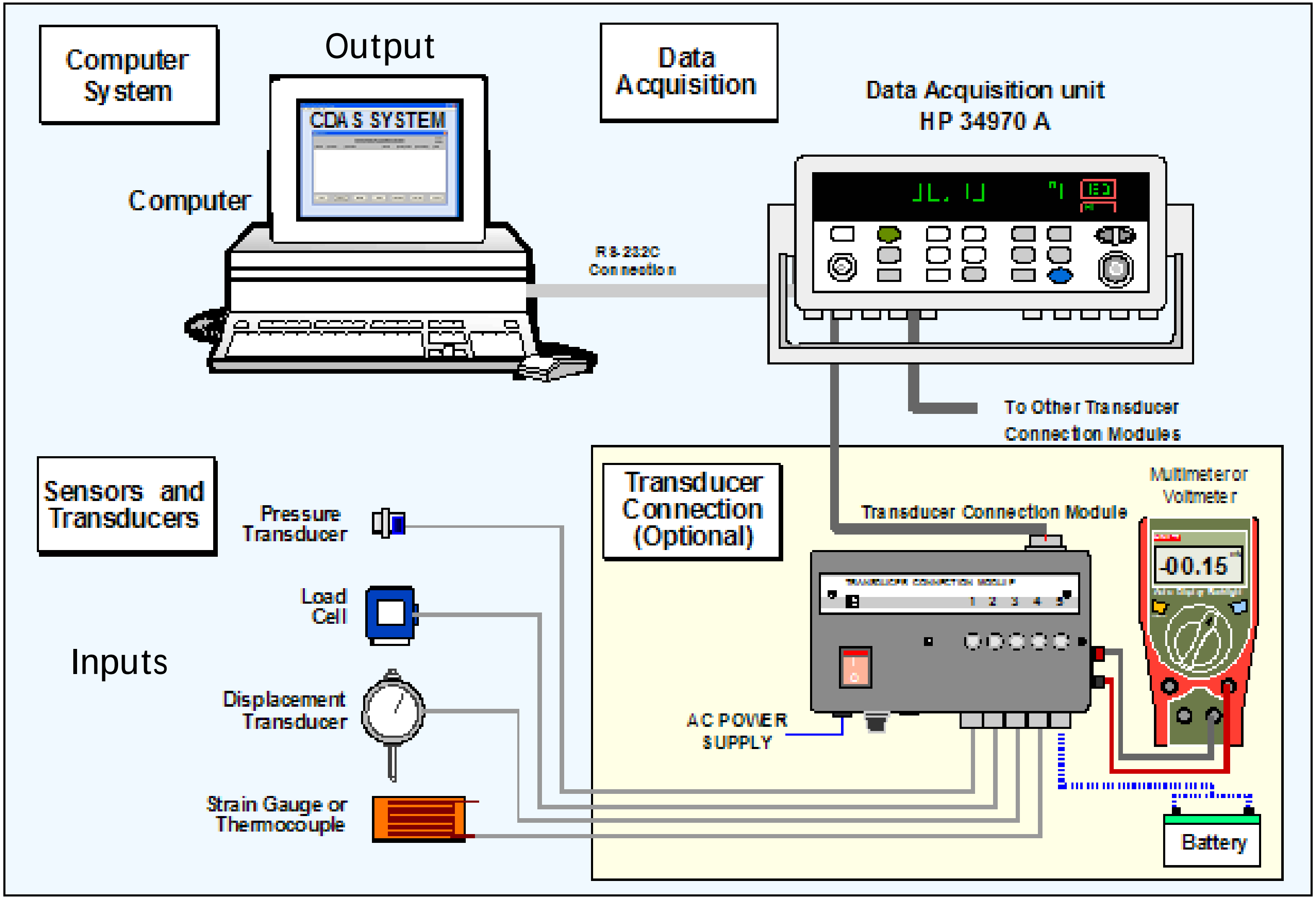
The programmed output of the microprocessor which is digital in nature in now finally fed to the computing device such as computers for the final processing, recording and displaying. The communication of the processed and programmed data from the data acquisition unit to the computer is initiated by using a RS-232 fast communication interface.

RS-232 communication interface

Operation:-

In the architecture shown A1, A2…An and S/H1, S/H2…S/Hn are the amplifiers and sample and hold circuit corresponding to different sensing element respectively. So as to get a digital form of an analog signal the analog signal is periodically sampled (its instantaneous value is acquired by circuit), and that constant value is held and is converted into a digital words. Any type of ADC must contain or proceeded by, a circuit that holds the voltage at the input to the ADC converter constant during the entire conversion time.

Conversion times vary widely, from nanoseconds (for flash ADCs) to microseconds (successive approximation ADC) to hundreds of microseconds (for dual slope integrator ADCs).ADC starts conversion when it receives start of conversion signal (SOC) from the processor and after conversion is over it gives end of conversion signal to the processor. Outputs of all the sample and hold circuits are multiplexed together so that we can use a single ADC, which will reduce the cost of the chip. Offset compensation and correction comprises of an ADC for measuring a reference voltage and other for the zero. Dedicating two channels of the multiplexer and using only one ADC for whole system can avoid the addition of ADC for this. This is helpful in offset correction and zero compensation of gain due to temperature drifts of acquisition chain.



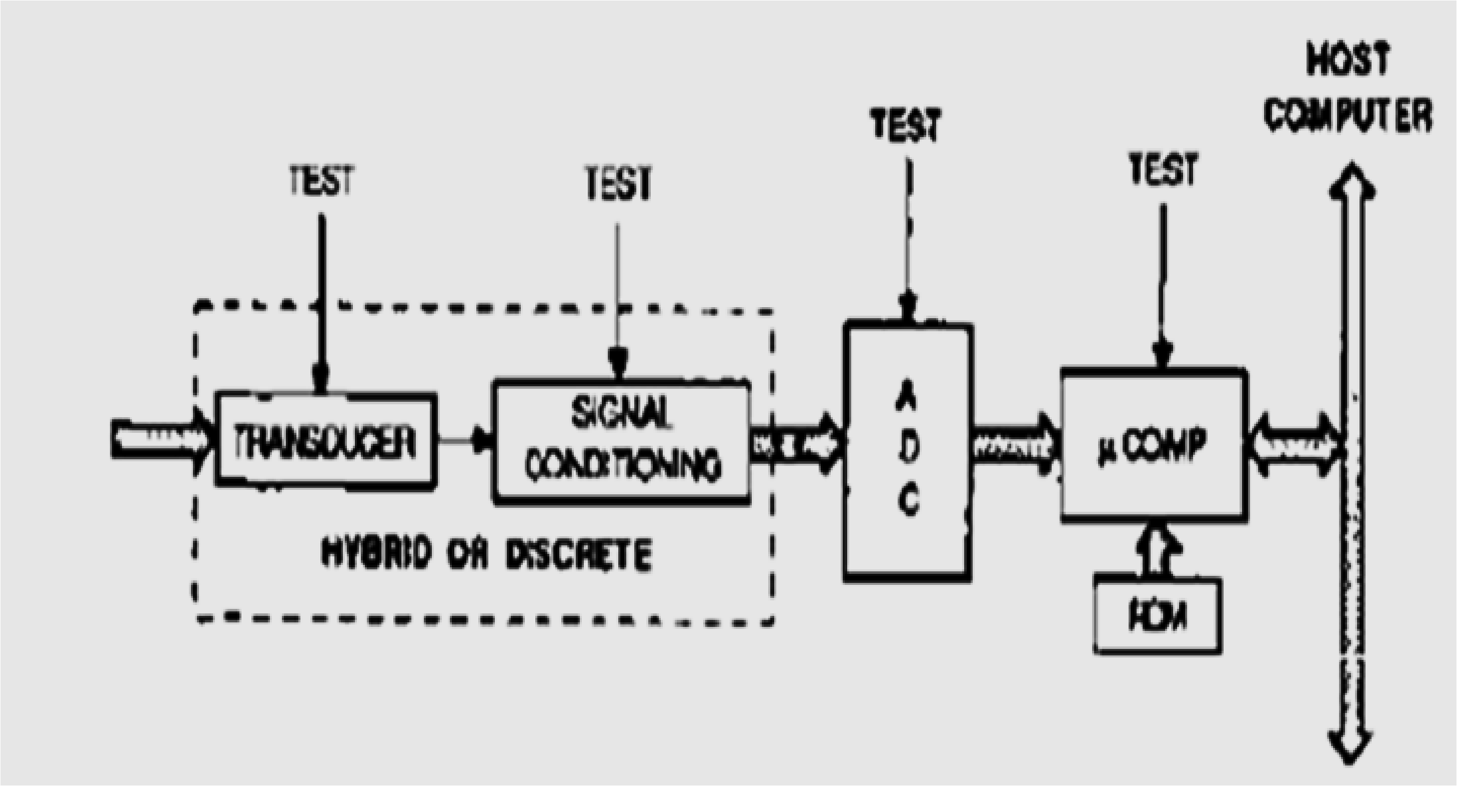
Operation of smart sensor

Evolution of Smart sensors:-

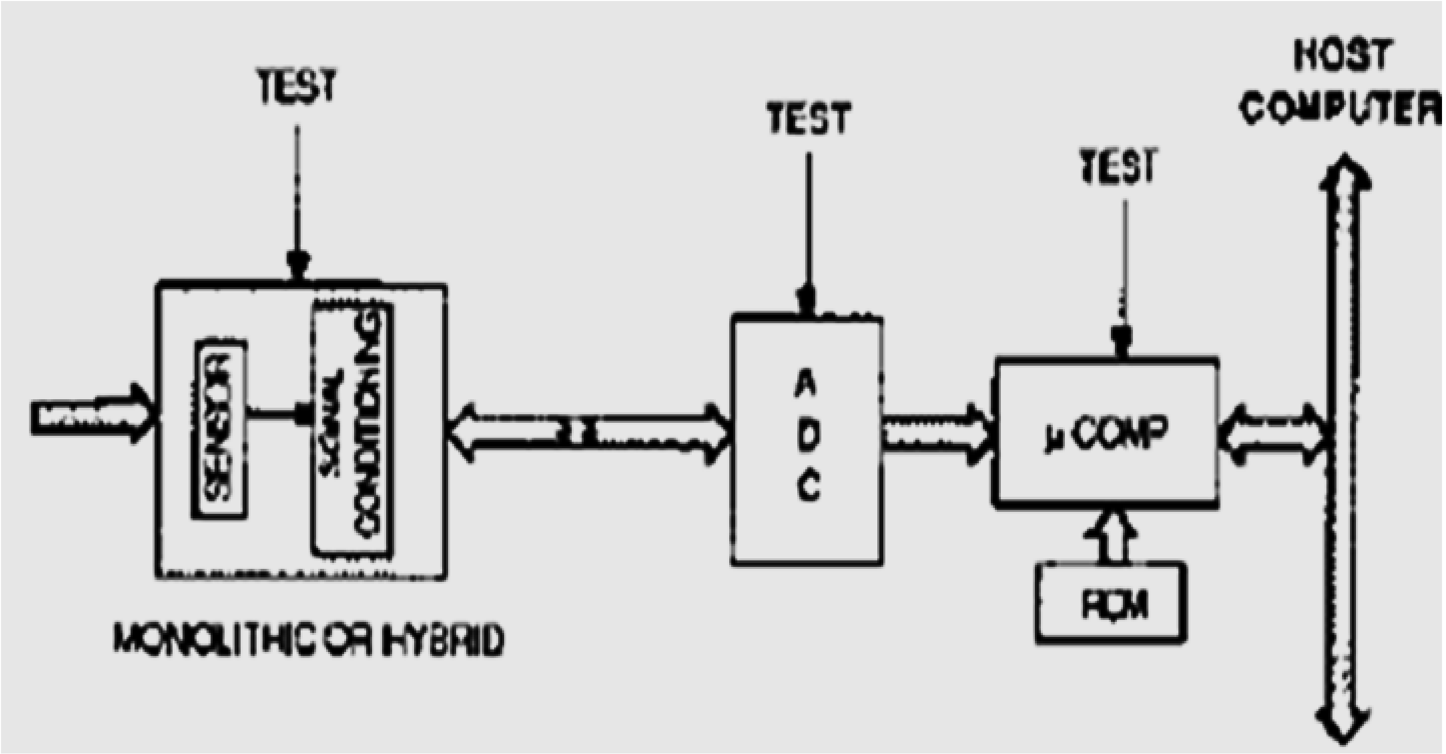
First generation devices had little, if any electronics associated with them.

Second generation sensors were part of purely analog systems with virtually all of the electronics remote from the sensor.

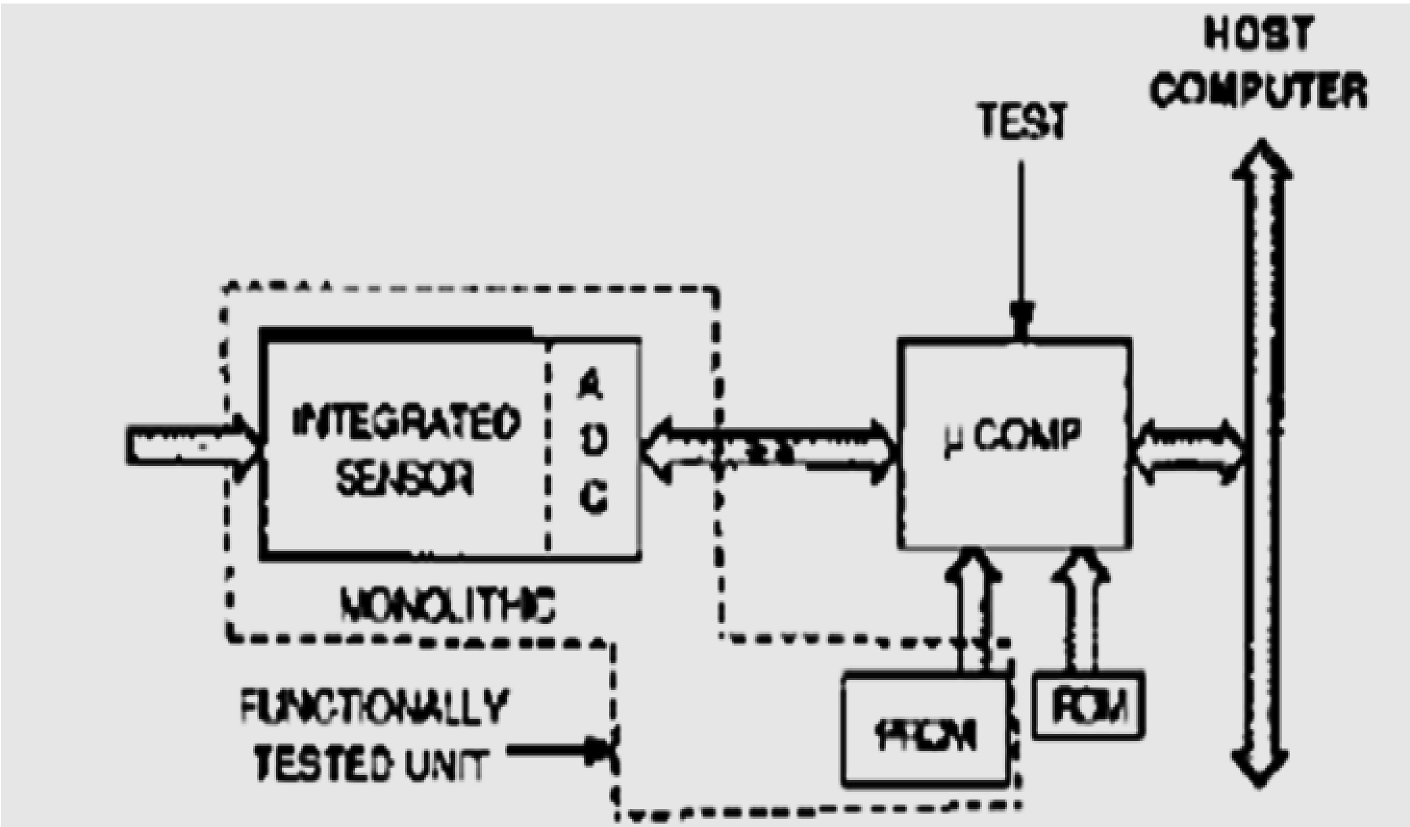
Third generation smart sensor



Fourth generation smart sensor



Fifth generation smart sensor



Applications:-

- General Applications
- Industrial Applications
- Medical Applications

General Applications:

Smart sensor enhances the following applications:

- *Self calibration:* Adjust deviation of o/p of sensor from desired value.
- *Communication:* Broadcast information about its own status.
- *Computation:* Allows one to obtain the average, variance and standard deviation for the set of measurements.
- *Multisensing:* A single smart sensor can measure pressure, temperature, humidity, gas flow and infrared, chemical reaction surface acoustic vapour etc.

Industrial Applications:

- Accelerometer
- Optical Sensor
- Infra red detector
- Structural Monitoring
- Geological Mapping

Accelerometer

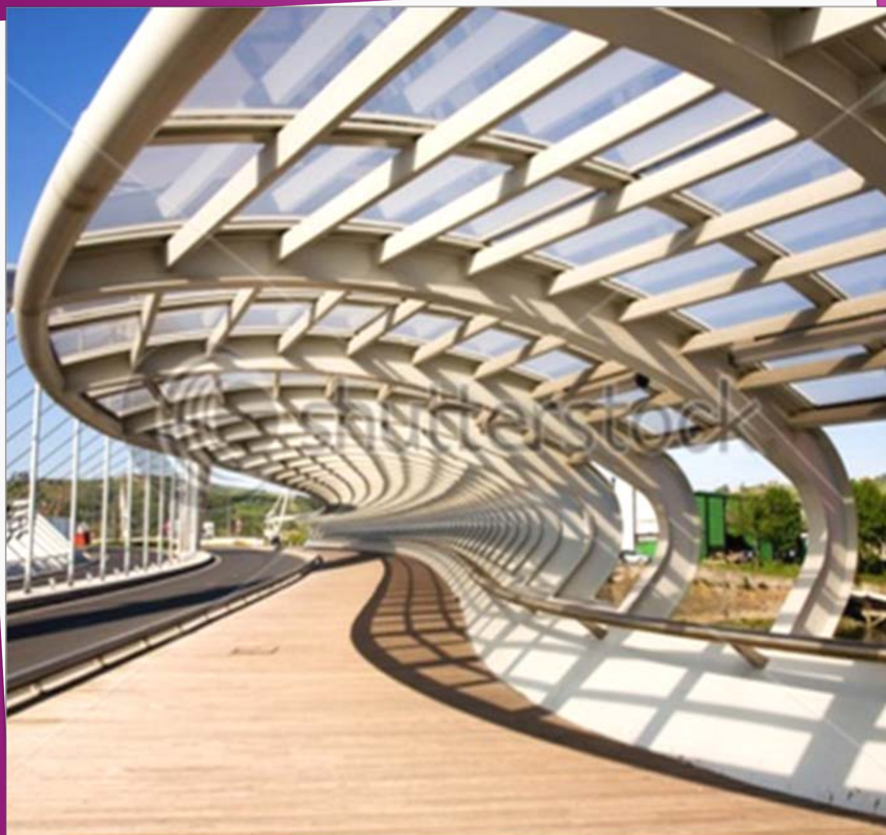
It consists of the sensing element and electronics on silicon. The accelerometer itself is a metal-coated SiO2 cantilever beam that is fabricated on silicon chip where the capacitance between the beam and the substrate provides the output signal.

Optical Sensor

Optical sensor is one of the examples of smart sensor, which is used for measuring exposure in cameras, optical angle encoders and optical arrays. Similar examples are load cells silicon based pressure sensors.

Infrared Detector Array

It is developed at solid laboratory of university of Michigan. Here infrared sensing element is developed using polysilicon.



Structural Monitoring

Smart sensors so implemented for this application are used for detecting any type of defects or fractures in the structures or infrastructures.

Geological Mapping

It is needed mainly to detect the minerals on the geological areas.

Digital imaging & interpretation of tunnel geology.

Remote measurements of tunnel response.

Medical Applications:

- Food safety
- Biological hazard detection
- Safety hazard detection and warning
- Environmental monitoring both locally and globally
- Health monitoring
- Medical diagnostics

Conclusion:-

A sensor is an element that produces a signal relating to the quantity to be measured.

Sensors + Interfacing hardwares=Smart sensors.

Architecture of a smart sensor consists of sensing element, DAS, programming and necessary network peripherals.

Operation is through sensing, signal conditioning and signal processing, programming , storage, communication and displaying.

Smart sensor technology is widely used in industrial and medical applications.

References:-

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